Beam background and detector considerations

International MUON Collider Collaboration

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The Beam-Induced Background

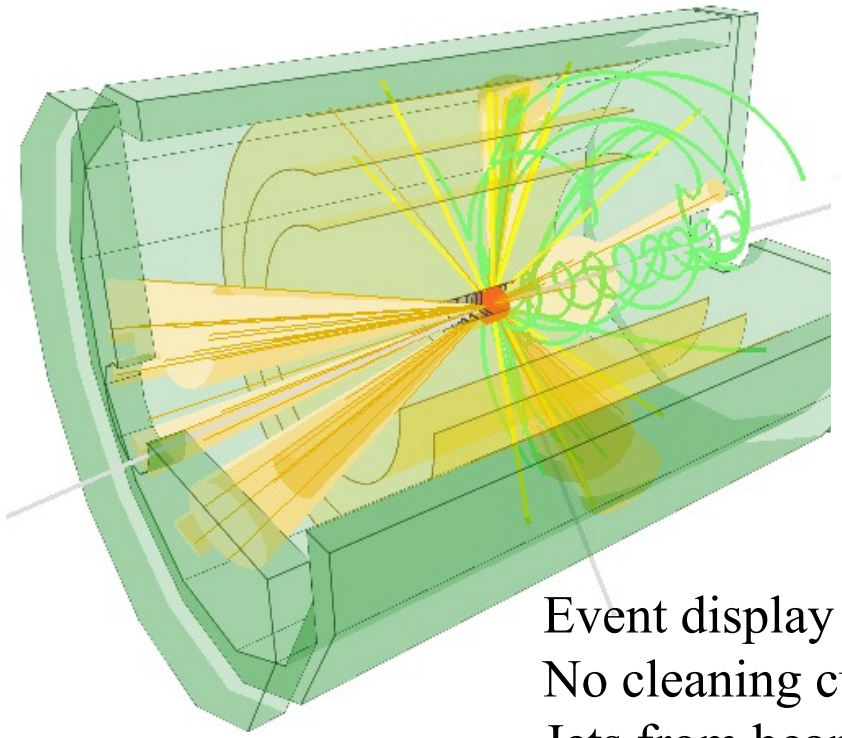
The high luminosity requires:

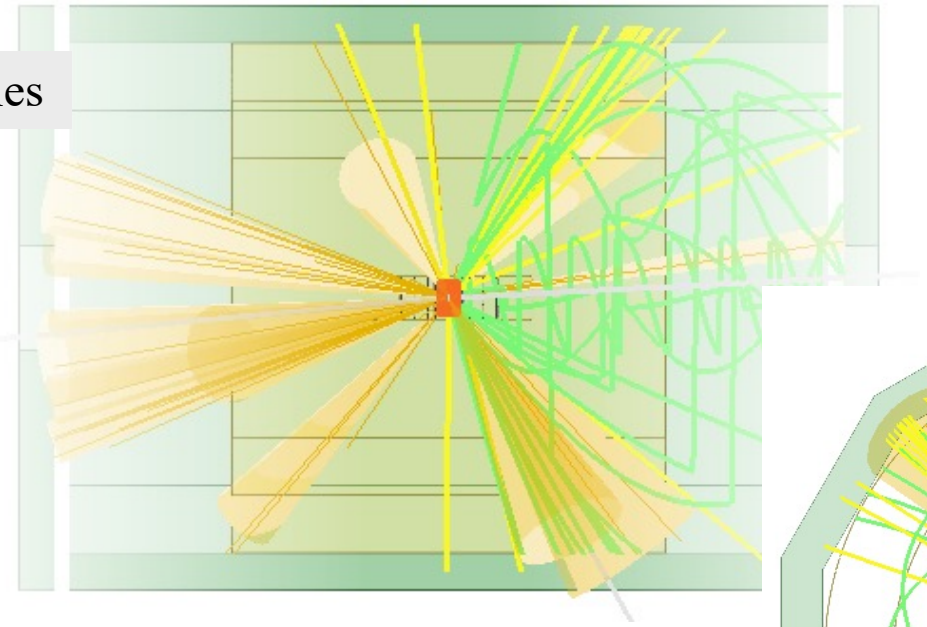
- Low beta-function at the IP (few cm)
- High number of muons per bunch ($N_\mu \sim 2 \cdot 10^{12}$)

Muons decay particles: 4×10^5 decays per meter of lattice, E_{beam} = 0.750 TeV with $2\times10^{12}\,\mu$/bunch
mainly: electrons/positrons, photons, neutrons, charged hadrons and muons

High Precision Measurements are possible:
$\mu^+\mu^- \rightarrow Hx \rightarrow b\bar{b}$x with Beam-Induced Background at 3 TeV

Yellow/green tracks: Montecarlo particles

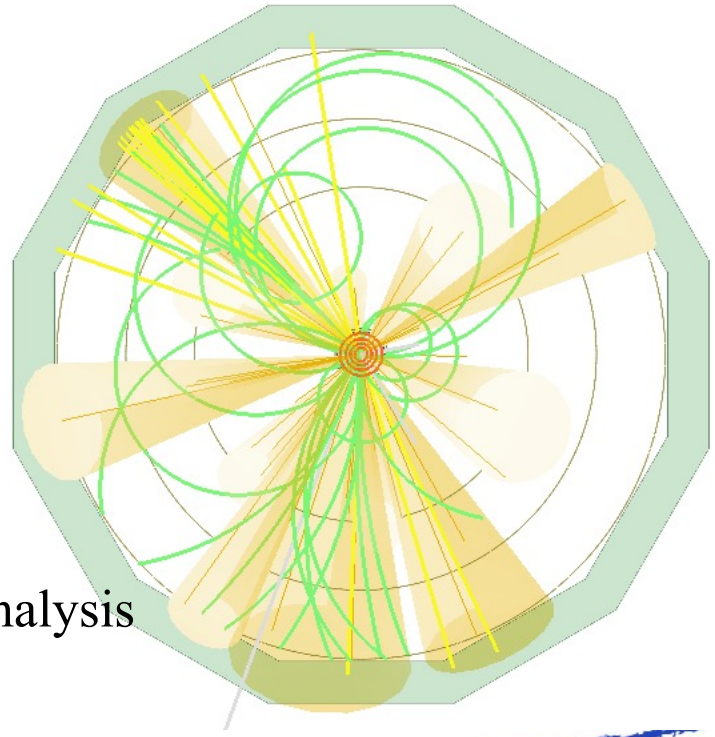




ECAL

Inner/Outer Tracker

Vertex Detector



Event 1300, Run 13

Event display after the reconstruction

No cleaning cuts, no analysis requirements

Jets from beam background removed during the analysis

The Beam-Induced Background Mitigation

The high luminosity requires:

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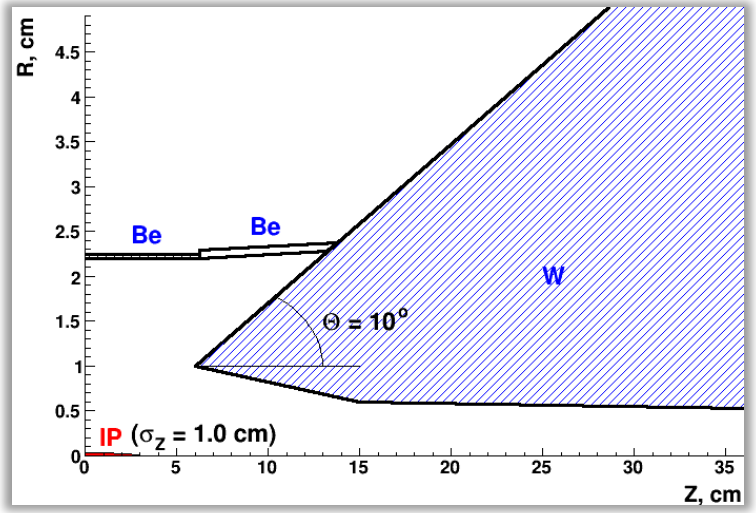
Muons decay particles: 4×10^5 decays per meter of lattice, E_{beam}= 0.750 TeV with $2\times10^{12}\,\mu$/bunch
mainly: electrons/positrons, photons, neutrons, charged hadrons and muons

So far, the best way to mitigate the particle fluxes effects on detector is the nozzles, two shielding cones entering in the detector.



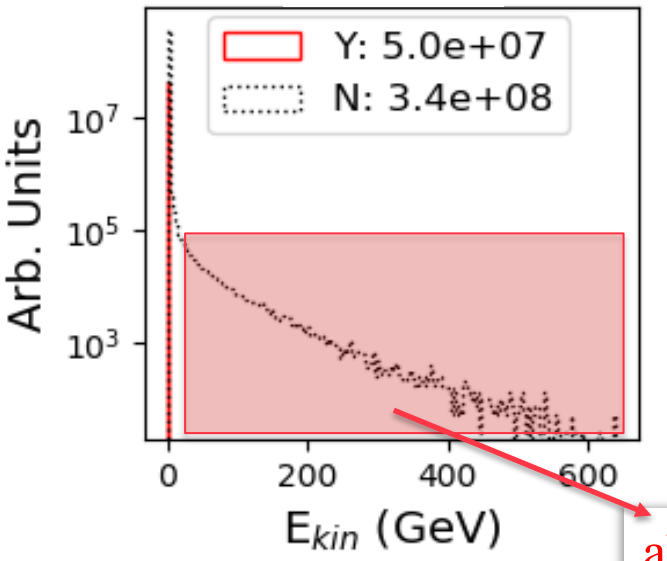
Di Benedetto et al., *A study of muon collider background rejection criteria in silicon vertex and tracker detectors*. Journal of Instrumentation13(2018)

What the nozzles do?

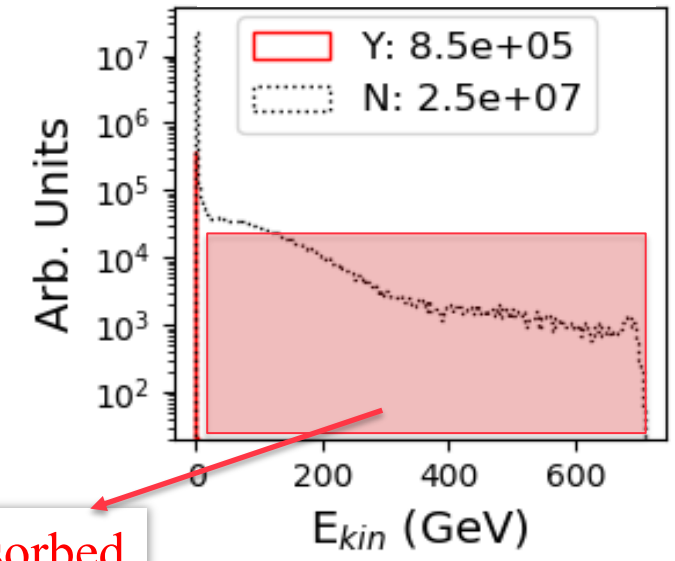
F. Collamati et al. 2021 JINST 16 P11009

Muon beam 0.75 TeV

Photons



electrons/positrons

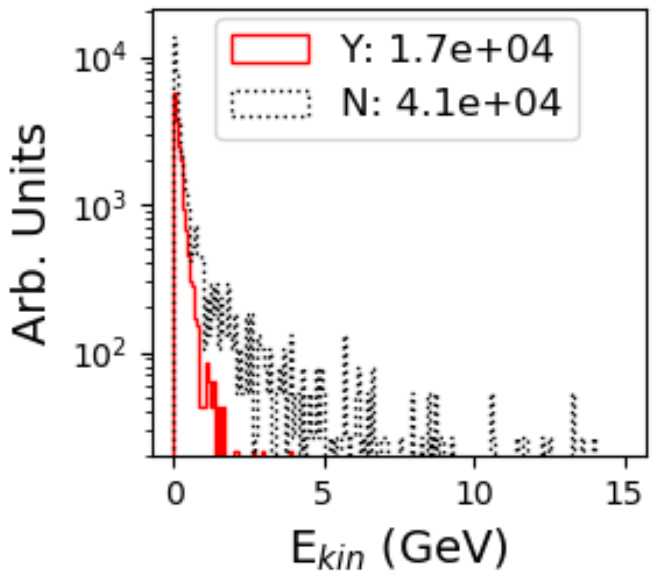


absorbed

Change cladding materials?
Lythium Polyethylene instead of BCH2?

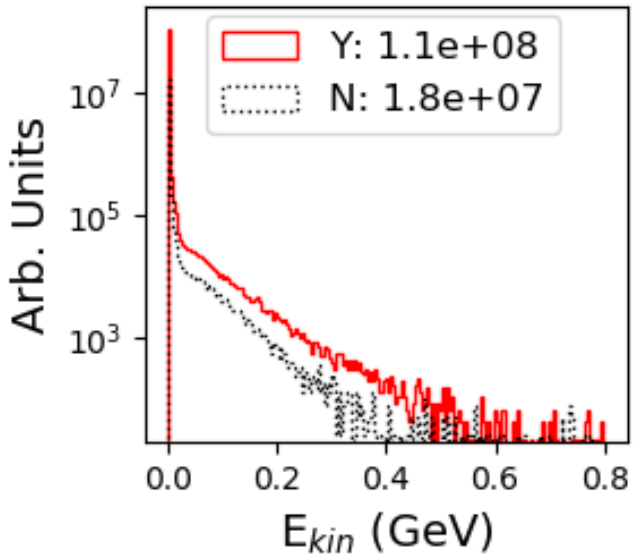
charged hadrons

Charged hadrons absorbed



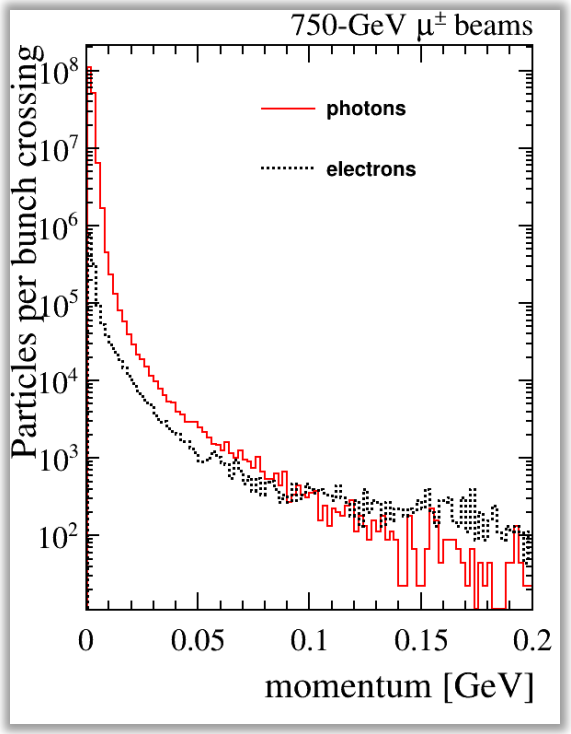
neutrons

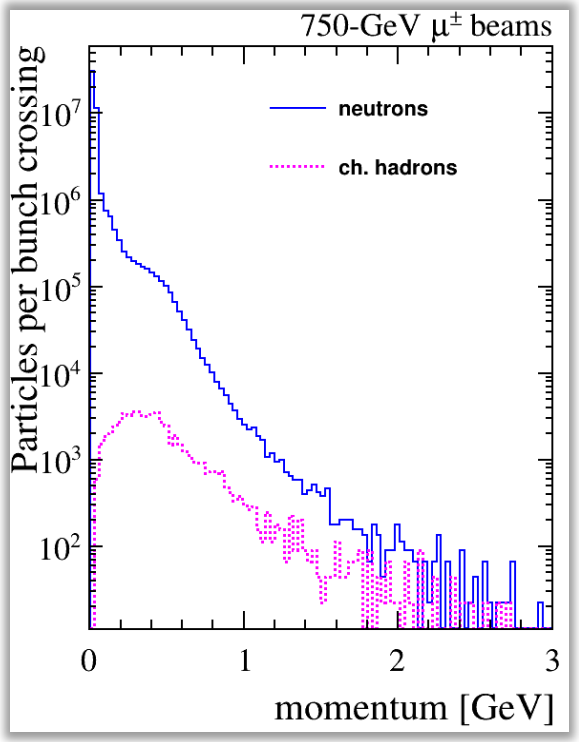
Neutrons increased

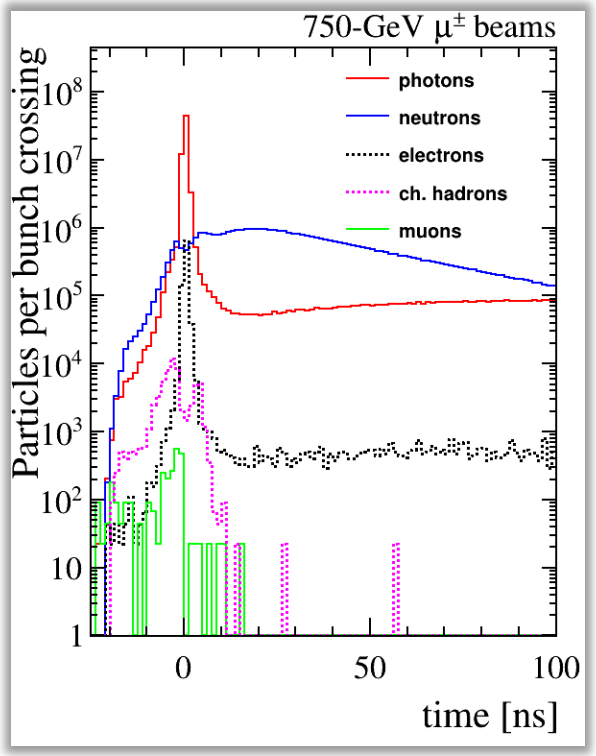


Beam-Induced Background Properties

N. Bartosik *et al* 2020 *JINST* **15** P05001







- Low momentum particles
- Partially out of time with respect to beam crossing t_0

hadronic calorimeter

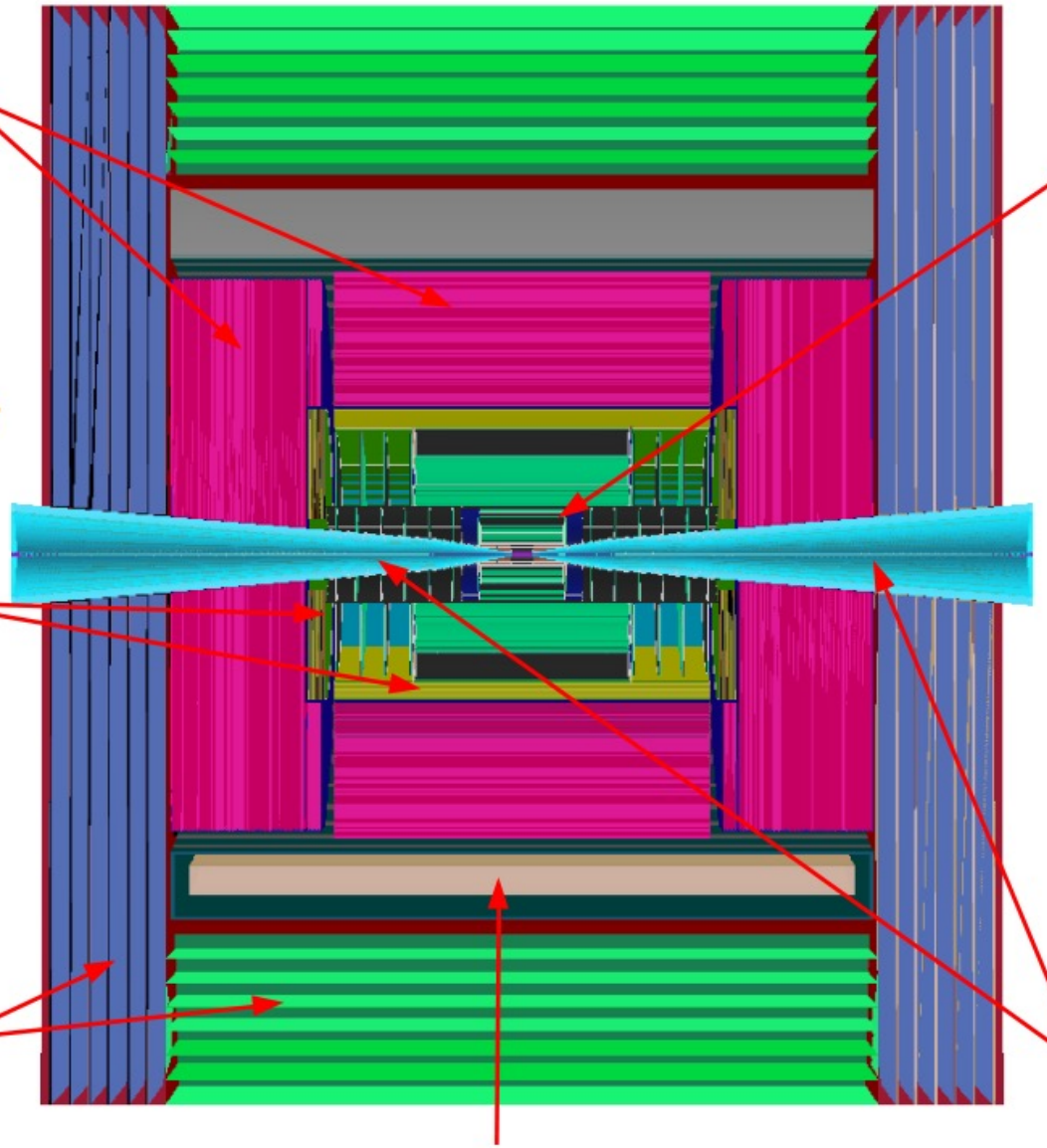
- 60 layers of 19-mm steel absorber + plastic scintillating tiles;
- 30x30 mm^2 cell size;
- 7.5 λ_I.

electromagnetic calorimeter

- 40 layers of 1.9-mm W absorber + silicon pad sensors;
- 5x5 mm^2 cell granularity;
- 22 X_0 + 1 λ_I.

muon detectors

- 7-barrel, 6-endcap RPC layers interleaved in the magnet's iron yoke;
- 30x30 mm^2 cell size.



superconducting solenoid (3.57T)

tracking system

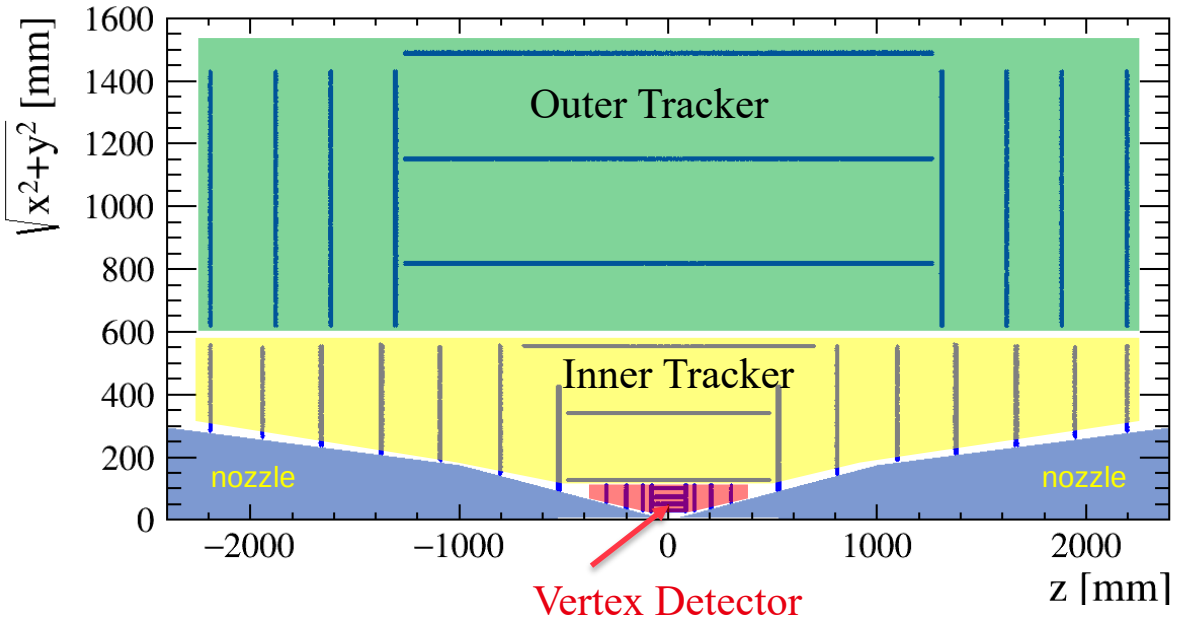
- Vertex Detector:
  - double-sensor layers (4 barrel cylinders and 4+4 endcap disks);
  - 25x25 μm^2 pixel Si sensors.
- Inner Tracker:
  - 3 barrel layers and 7+7 endcap disks;
  - 50 μm x 1 mm macro-pixel Si sensors.
- Outer Tracker:
  - 3 barrel layers and 4+4 endcap disks;
  - 50 μm x 10 mm micro-strip Si sensors.

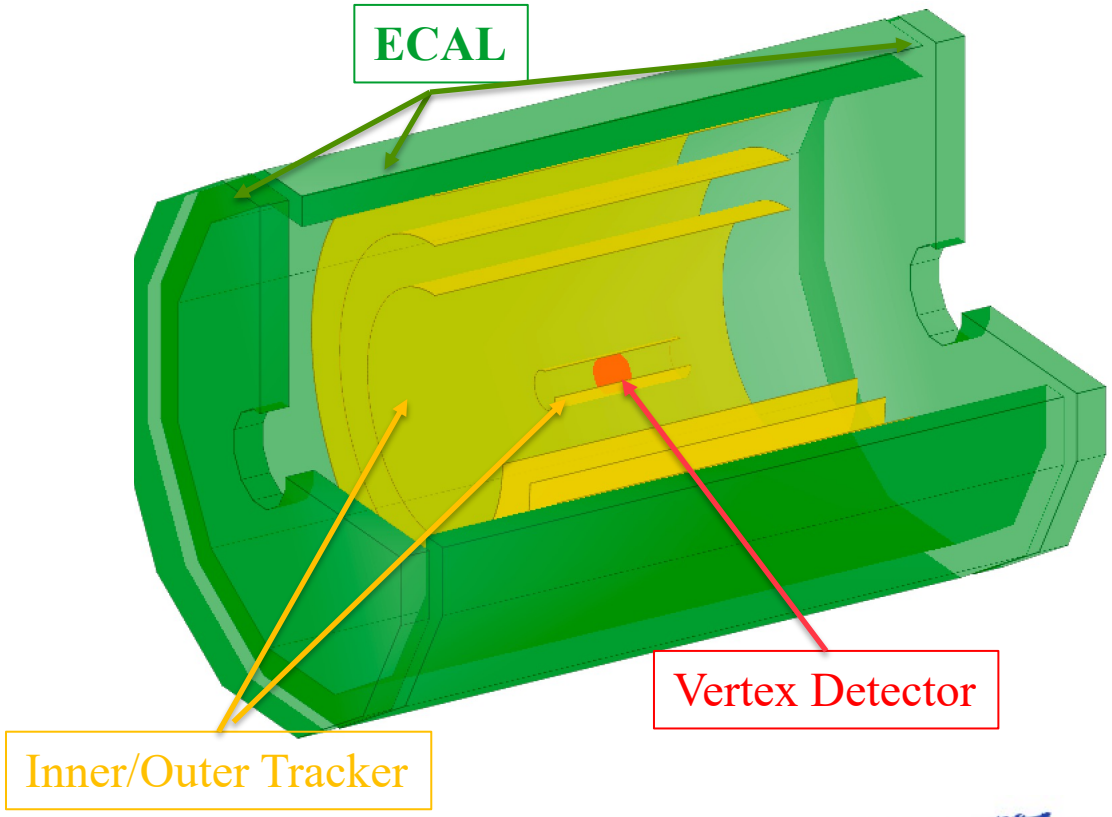
shielding nozzles

- Tungsten cones + borated polyethylene cladding.

Beam-Induced Background affects mainly tracker and electromagnetic calorimeter

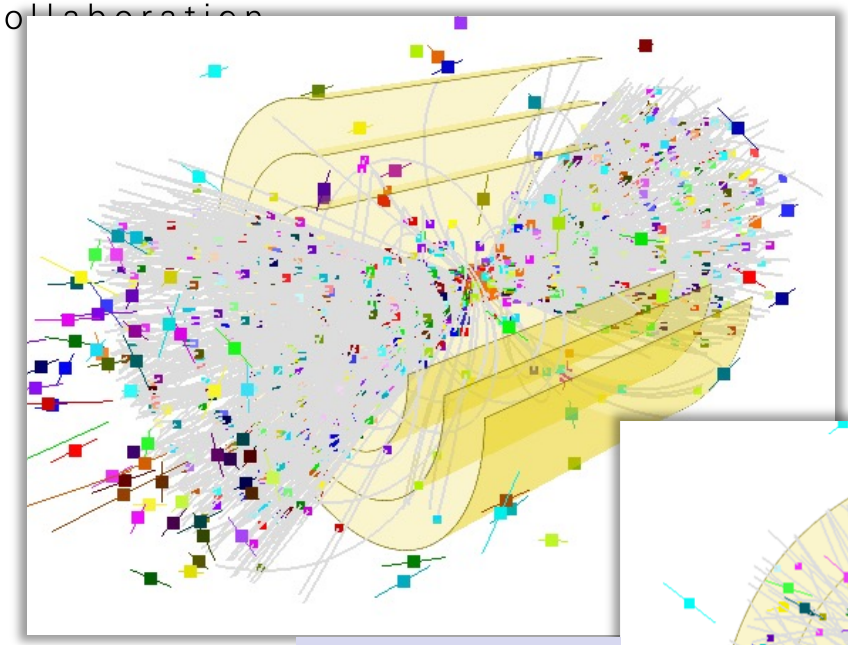
Only these two are discussed



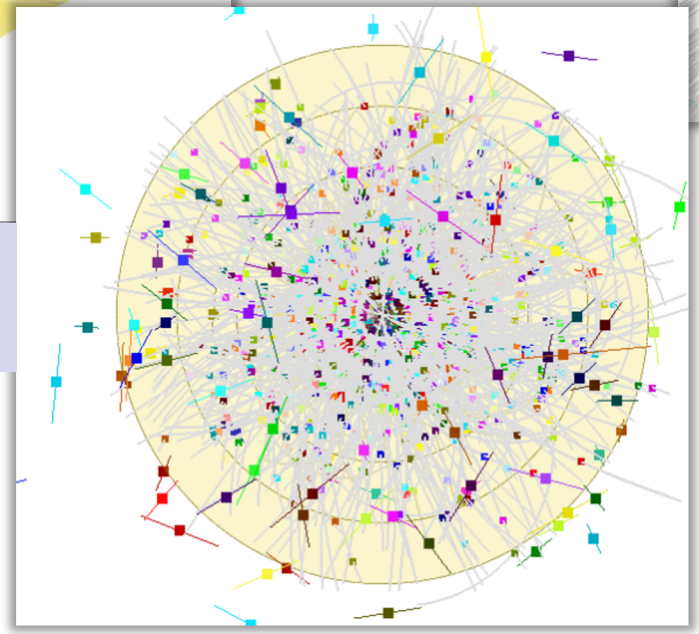


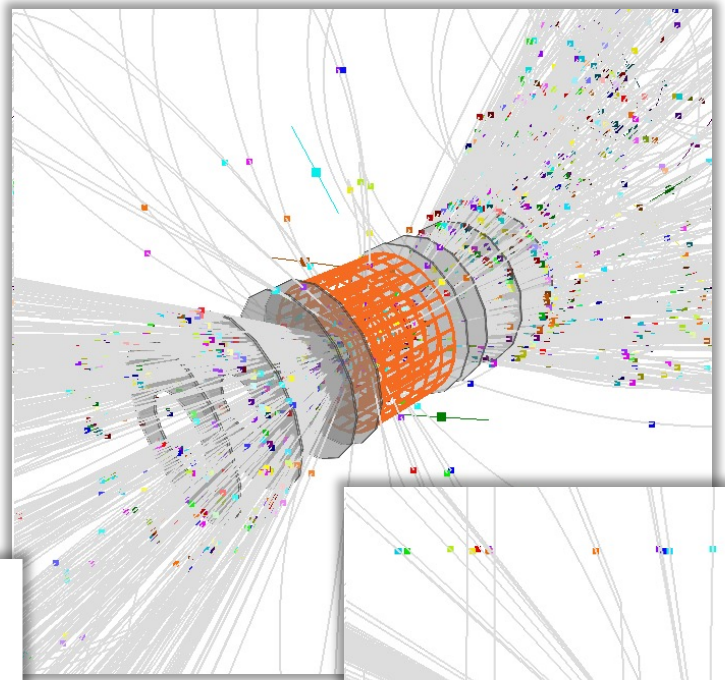
Beam-Induced Background in the Tracker

BIB events reconstruction
by Massimo Casarsa

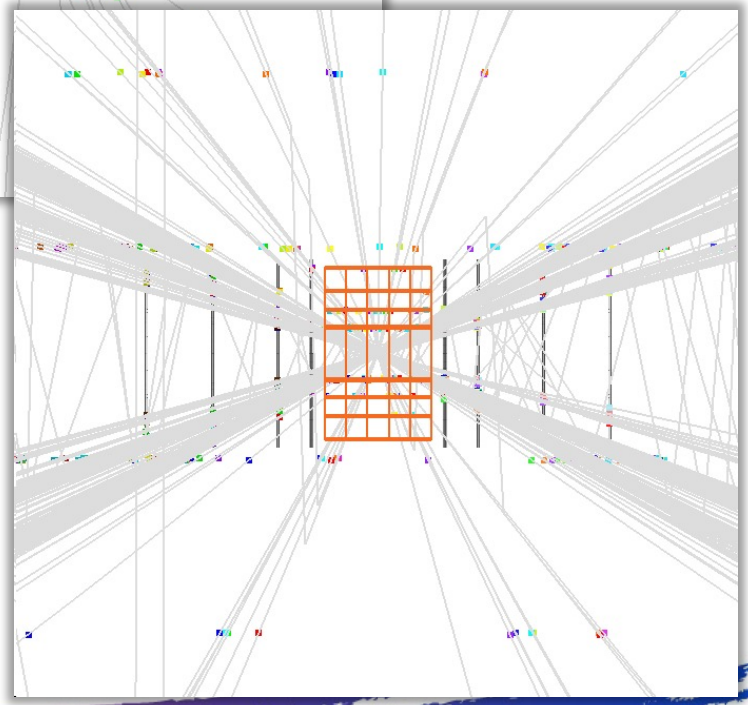


Inner/Outer Tracker





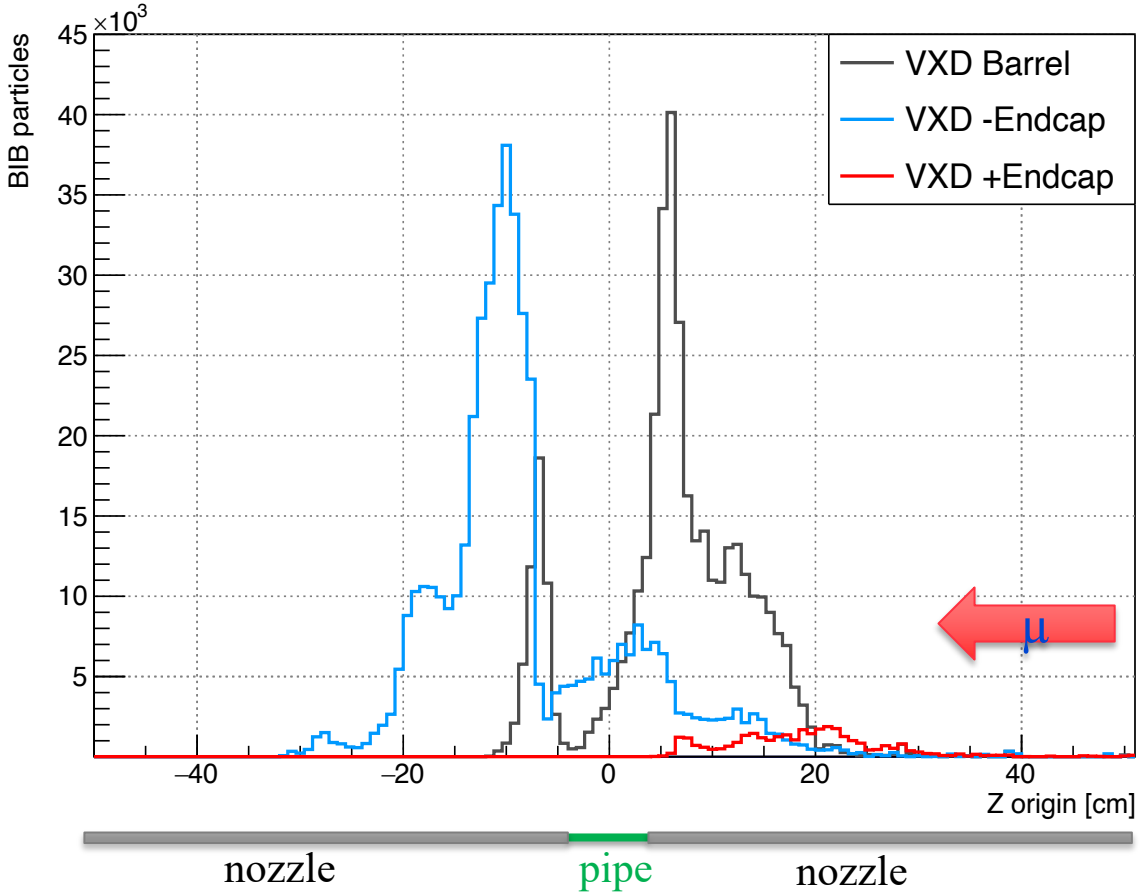
Vertex Detector



Origin of Beam-Induced Background in the Vertex Detector

Nazar Bartosik

One beam only, E = 0.750 TeV



Given a hit in the vertex tracker, central, backward (same side of beam), forward (opposite side of beam), z position of the original particle background that generated it.

Nozzle contributions on the barrel (same side) and on the other side for the endcap.

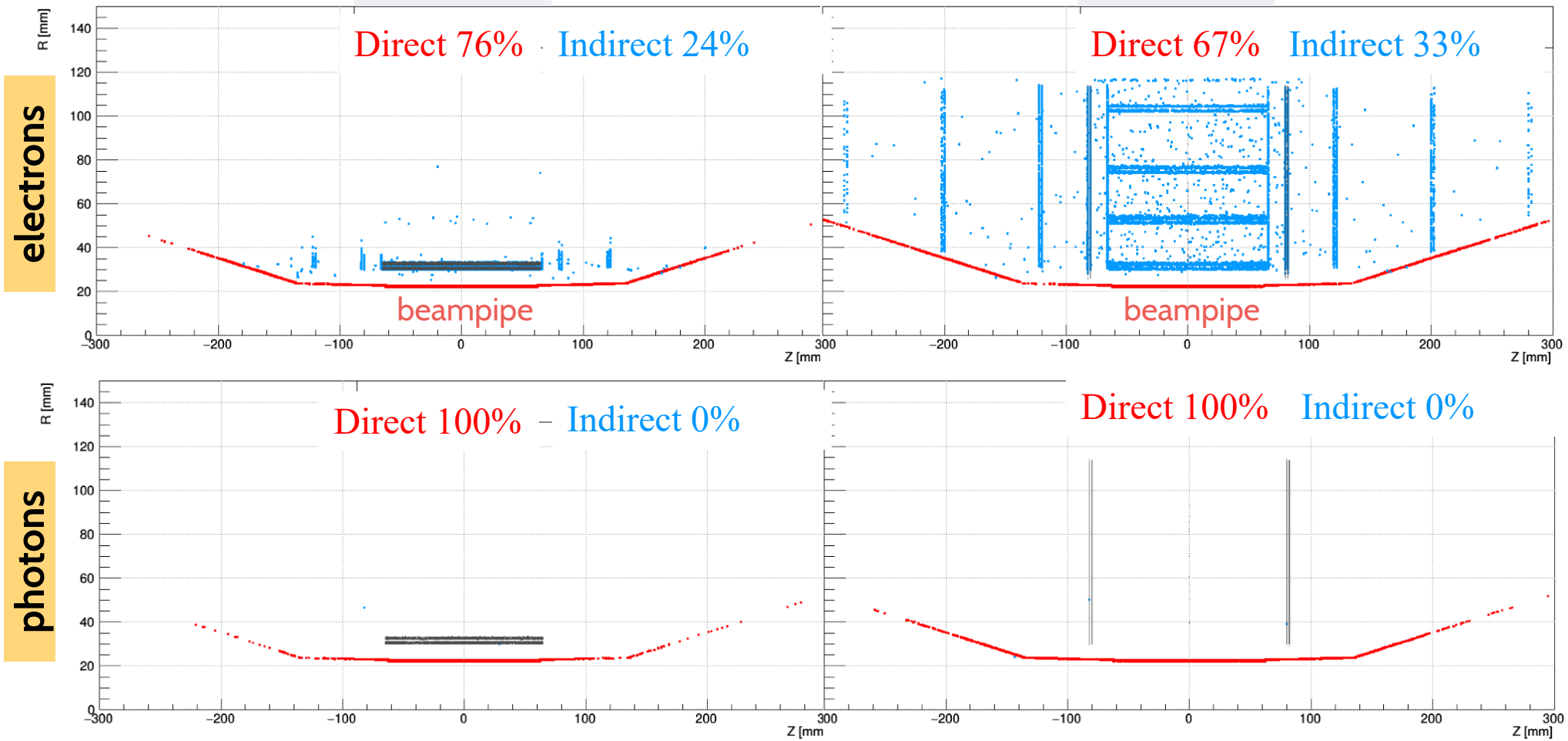
Beam-Induced Background in the Tracker Detector

Nazar Bartosik

International MUON Collider Collaboration

Electrons/ Positrons 80%

Photons 20%



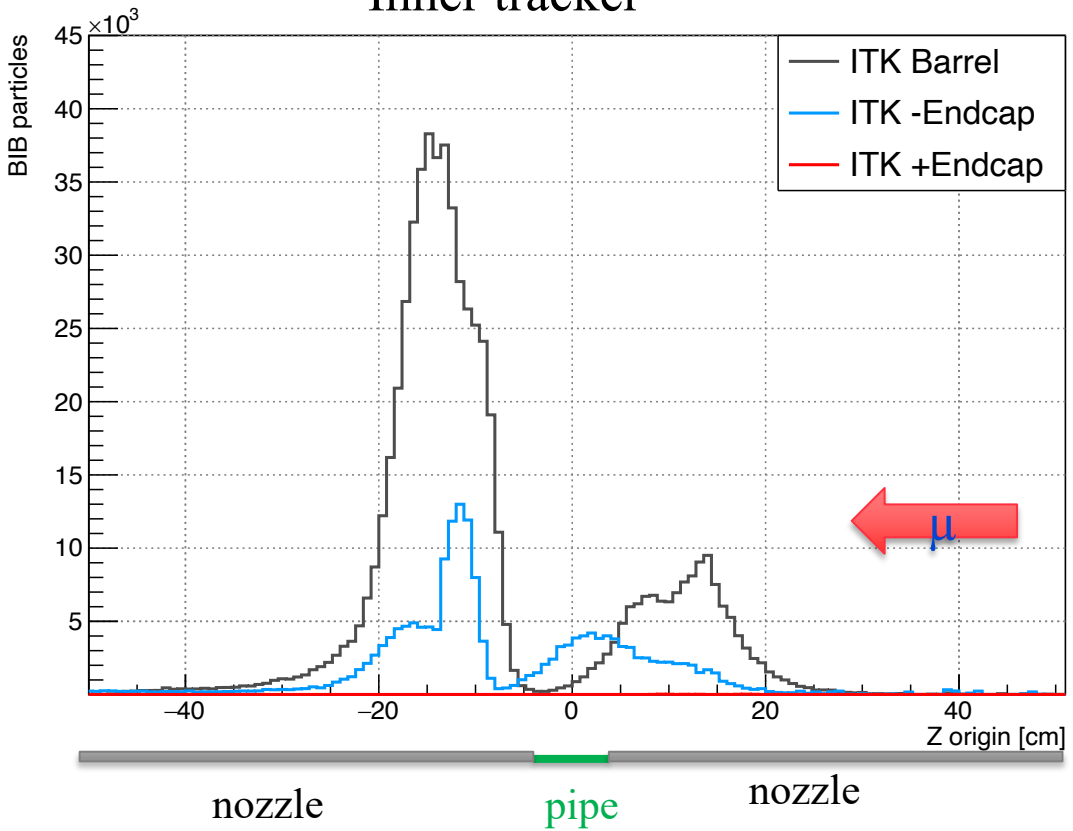
Direct beam background affects first layers of central and forward tracker (indirect sizeable)

Origin of Beam-Induced Background in the Tracker

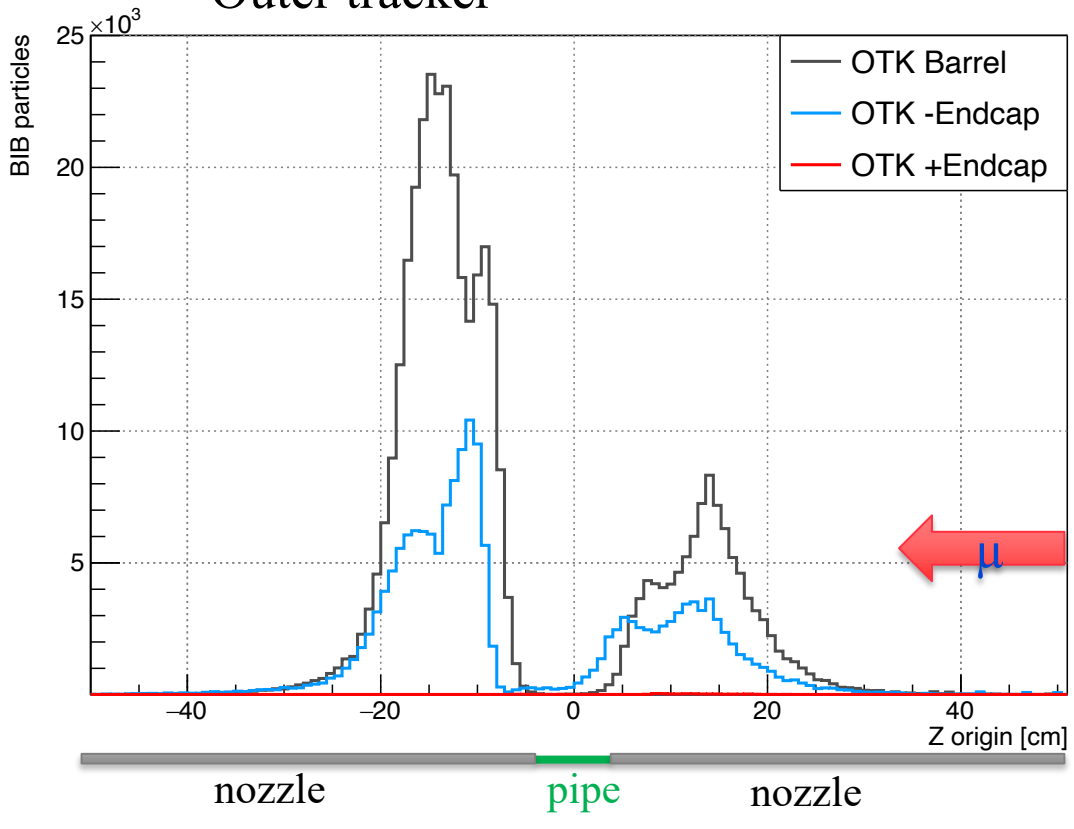
Nazar Bartosik

One beam only, E = 0.750 TeV

Inner tracker



Outer tracker



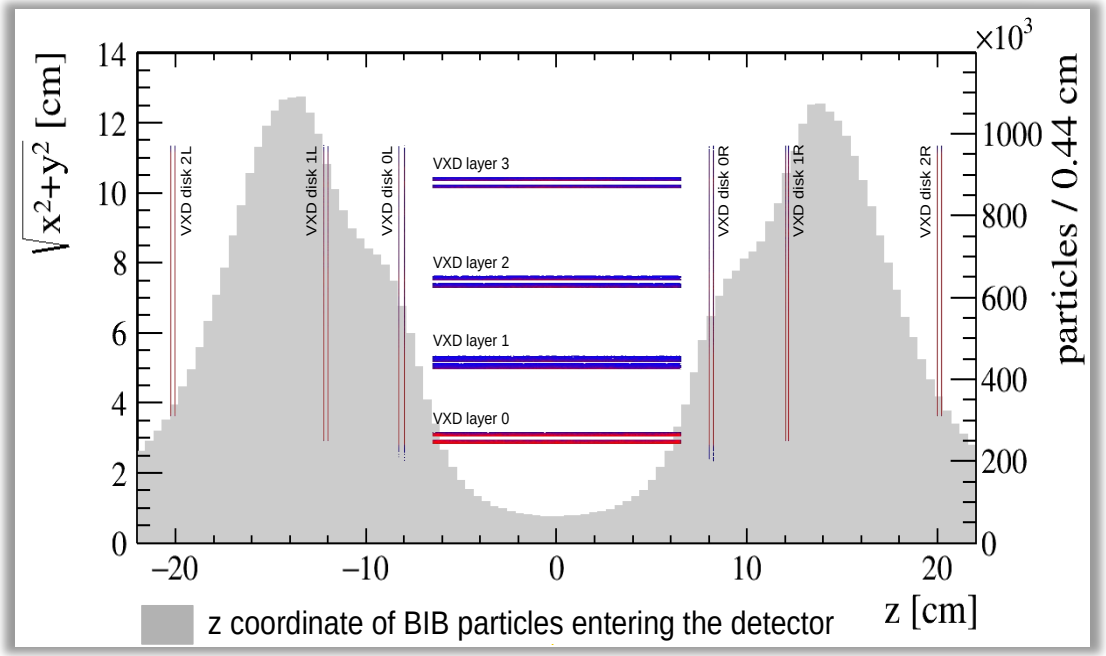
Given a hit in the tracker, central, backward (same side of beam), forward (opposite side of beam), z position of the original particle background that generated it.

Important contribution of back scattering on the nozzle on the other side

Considerations on Tracker

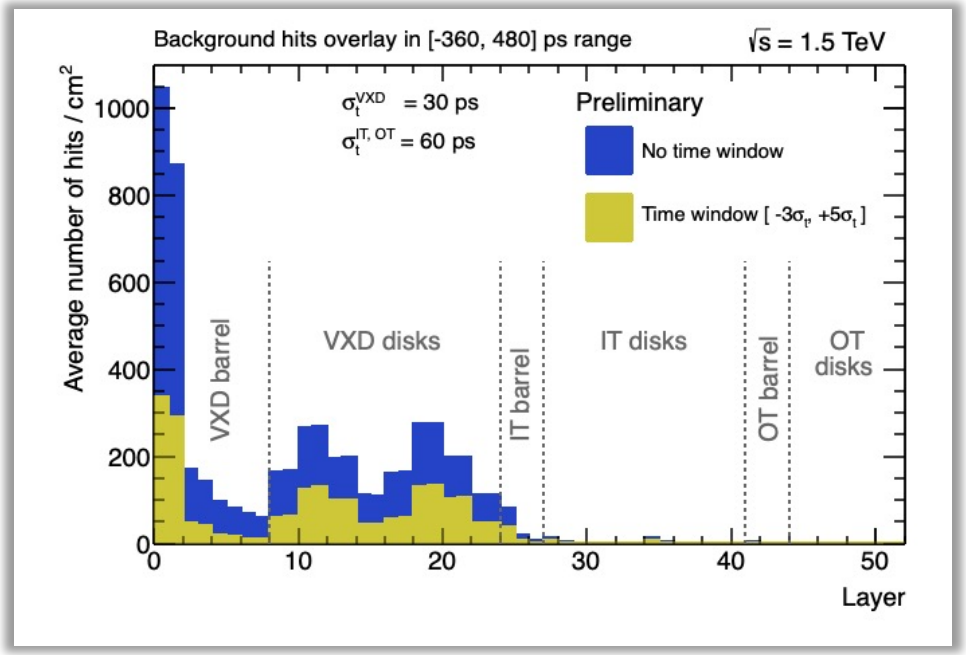
Design tracker avoiding beam hot spots, or design IR that do not generate hot spots.

Preliminary



Apply timing window to reduce hits from out-of-time background. Effectiveness at high energies to be studied.

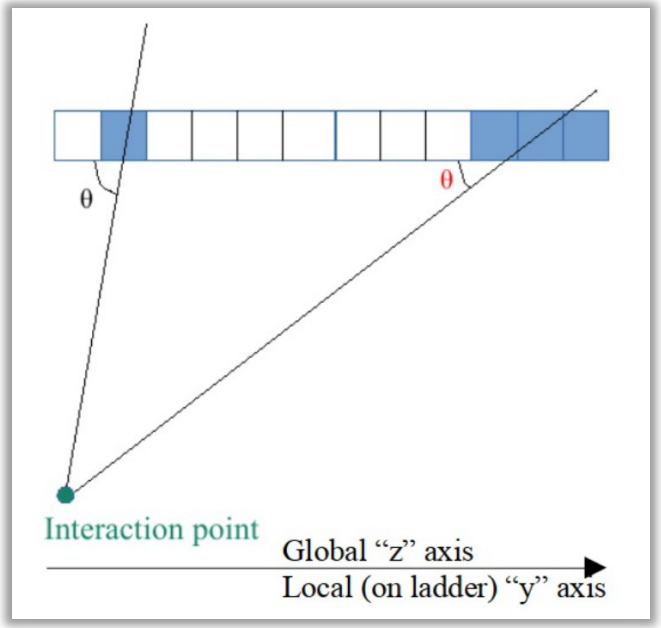
Preliminary

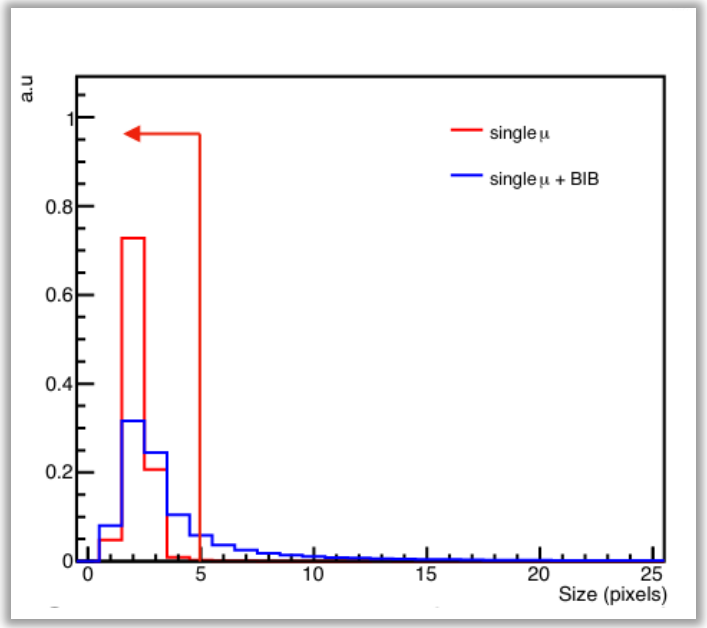


Sensor granularity and time resolution, layers configuration (tilted double layers, etc.), detector geometry and configuration to optimized

Use Directional Information at different stages

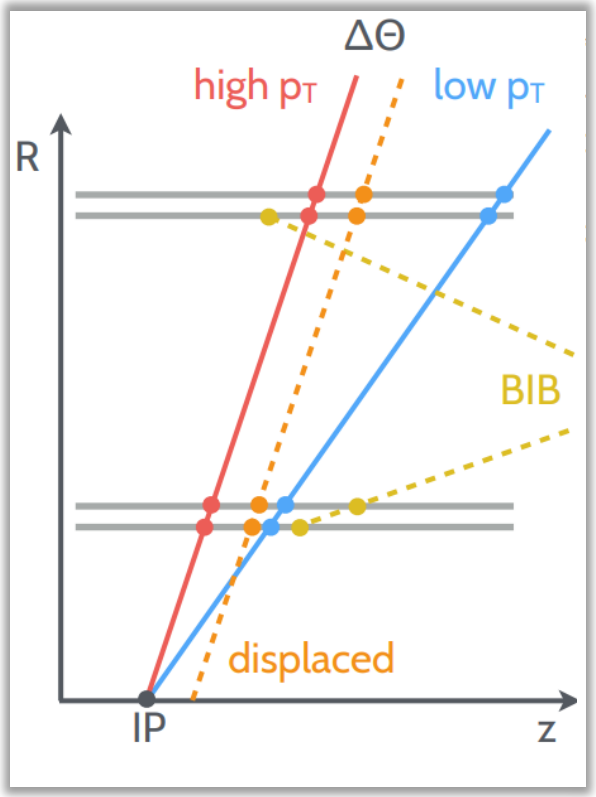
Realistic digitization reduce BIB hits





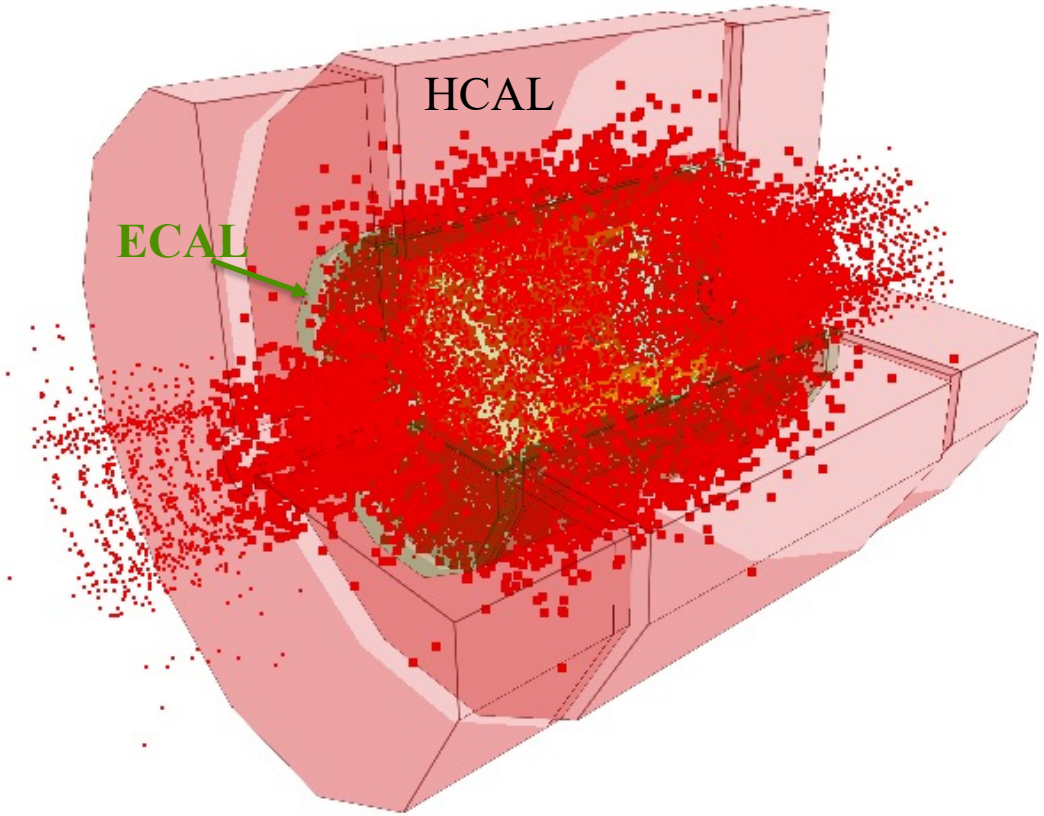
In progress, dedicated experienced person needed

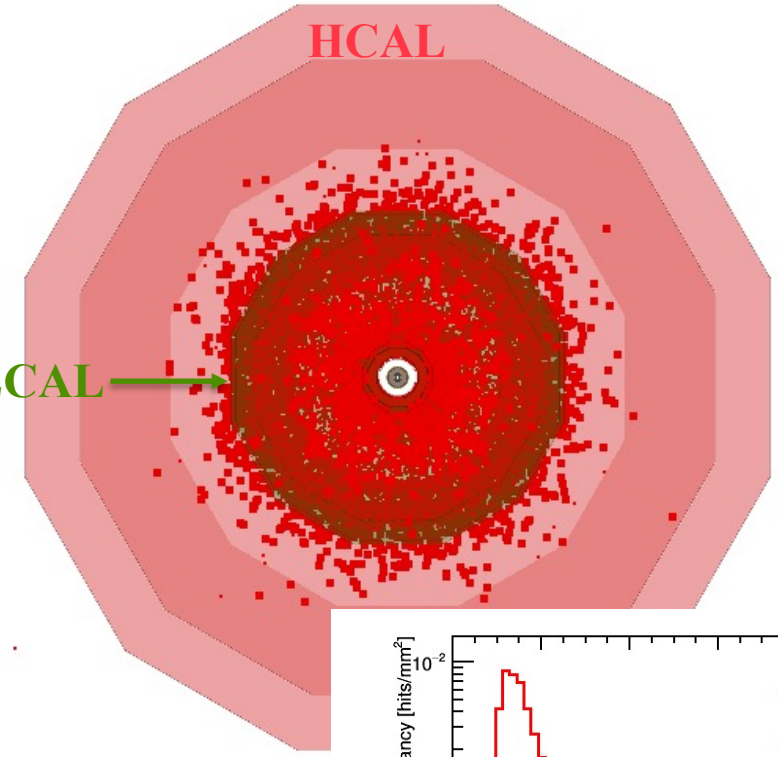
Correlation between two close layers could be very effective at pattern recognition

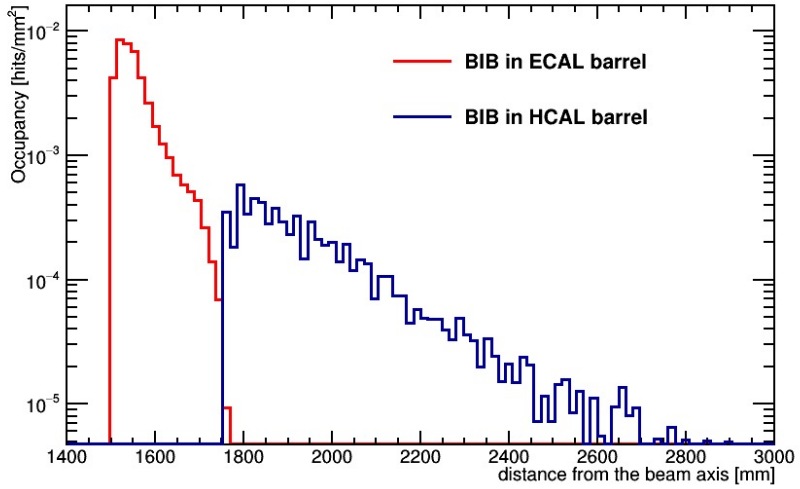


Need optimization to avoid bias on secondary particles

Beam-Induced Background in the Calorimeter



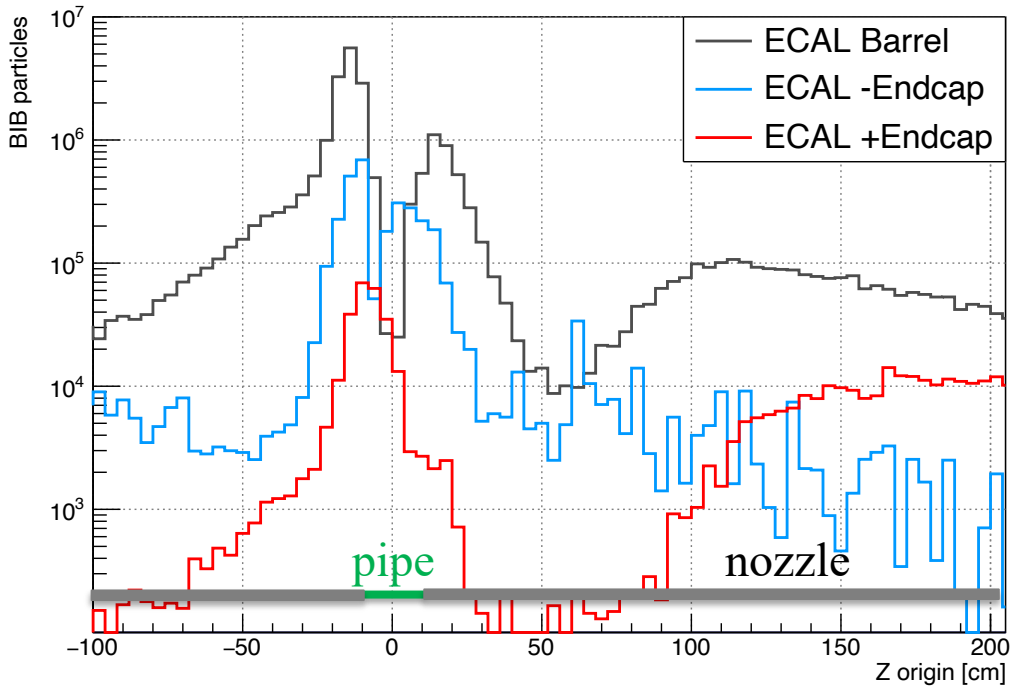




Beam background is not an issue for HCAL

Origin of Beam-Induced Background in the ECAL

Nazar Bartosik



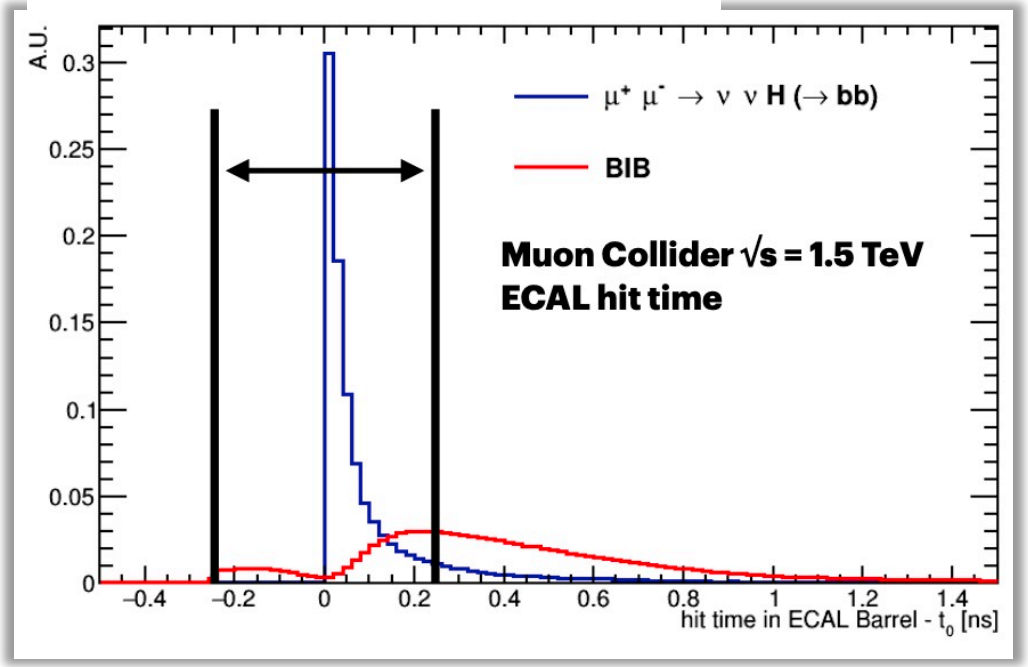
One beam only, 0.750 TeV
Given a hit in the EM calorimeter, central, backward (same side of beam), forward (opposite side of beam), z position of the original particle background that generated it.

Important contribution of back scattering on the nozzle on the other side

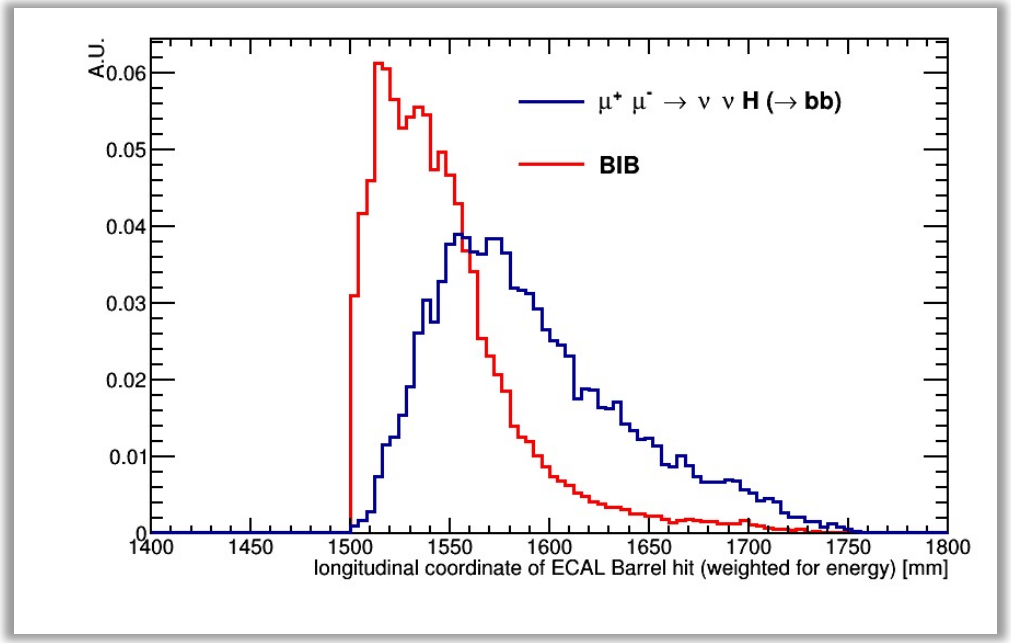
ECAL Beam Background Mitigation

Lorenzo Sestini

ECAL barrel hit arrival time – t_0



Optimization of the timing window will mitigate the beam background at acquisition time



Longitudinal shower profile is planned to be used in clusters reconstructions

Transversal shower profile still to be investigated

New calorimeter investigation: active/passive material, time information, granularity, etc.

To conclude

- Beam-Induced Background affects mainly tracker and ECAL.
- Study of the origin of the most relevant contributions to such a background in progress.
- Optimization of IR and detector design need to proceed in parallel, still to be done!

Very interesting activity specially for young scientists: possibility to design a detector together with accelerators experts since the very beginning!

Insert here your detector